Electronic Version
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Claims

[c1] 1.A method for in-line measurement by continuous Barkhausen noise detection, comprising the steps of:

creating one or more magnetic fields circumferentially positioned in a pipeline wall aligned and moving parallel with an axis of the pipeline;

sensing Barkhausen noise signals at one or more surfaces of the pipeline wall near one or more transition zones created by the one or more magnetic fields where there are strong magnetic field gradients;

amplifying, filtering, detecting, multiplexing and storing the sensed Barkhausen noise created by the moving magnetic fields; and

analyzing and interpreting the stored Barkhausen noise signals in relation to corresponding positions of the inspection pig within the pipeline for determining stress magnitude and corresponding locations of stress in the pipeline wall.

[c2] 2.The method of claim 1, wherein the step of creating one or more magnetic fields comprises:

positioning one or more magnets each having a

north pole and a south pole on the circumference of a cylindrically-shaped inspection pig movably contained within a pipeline;

aligning one or more magnetic fields produced by the one or more magnets for producing magnetic fields in a wall of the pipeline parallel to a longitudinal axis of the inspection pig and the pipeline; and

moving the inspection pig along the longitudinal axis of the pipeline.

[c3] 3.The method of claim 2, wherein the step of sensing Barkhausen noise signals comprises locating one or more magnetic sensors at transition zones adjacent to the poles of the one or more magnets and outside the one or more magnetic fields where there are strong magnetic field gradients in the pipeline wall for detecting Barkhausen noise in the pipeline wall.

[c4] 4.The method of claim 3, wherein the step of amplifying, filtering, detecting, multiplexing and storing comprises:

connecting the one or more magnetic noise sensors to instrumentation circuits in an instrumentation pack contained within the inspection pig; and

sensing Barkhausen noise signals for determining stress in the pipeline wall and storing the noise signals in the instrumentation pack as the inspection pig is caused to transit the pipeline along the longi-

tudinal axis of the pipeline.

[c5] 5.The method of claim 2, wherein the step of positioning one or more magnets is selected from the group consisting of positioning one or more permanent magnets and positioning one or more DC electromagnets magnets energized by a battery pack.

[c6] 6.The method of claim 3, further comprising the step of generating Barkhausen magnetic transitions in the transition zones in the pipeline wall as the inspection pig is caused to transit the pipeline.

[c7] 7.The method of claim 2, wherein the step of positioning one or more magnets further comprises positioning one or more magnets in close proximity to a wall of the pipeline.

[c8] 8.The method of claim 3, wherein the step of locating one or more magnetic sensors further comprises locating a multitude of small magnetic sensors for detecting small areas of pipe wall stress.

[c9] 9.The method of claim 3, wherein the step of locating one or more magnetic sensors further comprises locating a small number of large magnetic sensors providing improved signal-to-noise ratios for detecting large areas of pipe wall stress.

[c10] 10.The method of claim 3, wherein the step of locating one or more magnetic sensors further comprises locating one or more magnetic sensors over a radial angle of from 45 to 90 degrees of the circumference of the inspection pig for detecting only stresses due to bends in the pipeline wall.

[c11] 11.The method of claim 1, further comprising the step of enhancing detection of pipeline stress by making trending measurements of stored Barkhausen noise signals over a period of time for providing higher detection sensitivity than single absolute measurements of Barkhausen noise signals.

[c12] 12.The method of claim 4, wherein the step of connecting the one or more magnetic noise sensors comprises:

connecting the one or more magnetic noise sensors to input terminals of one or more amplifiers in the instrumentation pack;

connecting output terminals of the one or more amplifiers to input terminals of one or more filters in the instrumentation pack;

connecting output terminals of the one or more filters to input terminals of one or more detector circuits in the instrumentation pack;

connecting output terminals of the one or more de-

tector circuits to input terminals of a multiplexer in the instrumentation pack; and

connecting an output terminal of the multiplexer to a data storage device in the instrumentation pack for storing multiplexed Barkhausen noise data.

[c13] 13. The method of claim 2, wherein the steps of positioning one or more magnets and aligning one or more magnetic fields are included in an existing MFL inspection pig.

[c14] 14.A system for in-line measurement by continuous Barkhausen noise detection, comprising:

means for creating one or more magnetic fields circumferentially positioned in a pipeline wall aligned and moving parallel with an axis of the pipeline;

means for sensing Barkhausen noise signals at one or more surfaces of the pipeline wall in one or more transition zones created by the one or more magnetic fields where there are strong magnetic field gradients;

means for amplifying, filtering, detecting, multiplexing and storing the sensed Barkhausen noise created by the moving magnetic fields; and

means for analyzing and interpreting the stored Barkhausen noise signals in relation to corresponding positions of the inspection pig within the pipeline

for determining stress magnitude and corresponding locations of stress in the pipeline wall.

[c15] 15.The system of claim 14, wherein the means for creating one or more magnetic fields comprises:

one or more magnets each having a north pole and a south pole positioned on the circumference of a cylindrically-shaped inspection pig movably contained within a pipeline;

one or more magnetic fields produced by the one or more magnets for producing magnetic fields in a wall of the pipeline aligned parallel to a longitudinal axis of the inspection pig and the pipeline; and

means for moving the inspection pig along the longitudinal axis of the pipeline.

[c16] 16.The system of claim 15, wherein the means for sensing Barkhausen noise signals comprises one or more magnetic sensors located at transition zones adjacent to the poles of the one or more magnets and outside the one or more magnetic fields where there are strong magnetic field gradients in the pipeline wall for detecting Barkhausen noise in the pipeline wall.

[c17] 17.The system of claim 16, wherein the means for amplifying, filtering, detecting, multiplexing and storing comprises:

one or more magnetic noise sensors connected to instrumentation circuits in an instrumentation pack contained within the inspection pig; and

Barkhausen noise signals sensed for determining stress in the pipeline wall and stored in the instrumentation pack as the inspection pig is caused to transit the pipeline along the longitudinal axis of the pipeline.

[c18] 18.The system of claim 15, wherein the means for positioning one or more magnets is selected from the group consisting of means for positioning one or more permanent magnets and means for positioning one or more DC electromagnets magnets energized by a battery pack.

[c19] 19.The system of claim 16, further comprising the one or more magnets for generating Barkhausen magnetic transitions in the transition zones in the pipeline wall as the inspection pig is caused to transit the pipeline.

[c20] 20.The system of claim 15, wherein the one or more magnets are positioned in close proximity to a wall of the pipeline.

[c21] 21.The system of claim 16, wherein the one or more magnetic sensors further comprises a multitude of small magnetic sensors for detecting small areas of pipe wall

stress.

[c22] 22.The system of claim 16, wherein the one or more magnetic sensors further comprises a small number of large magnetic sensors providing improved signal-to-noise ratios for detecting large areas of pipe wall stress.

[c23] 23.The system of claim 16, wherein the one or more magnetic sensors further comprises one or more magnetic sensors located over a radial angle of from 45 to 90 degrees of the circumference of the inspection pig for detecting only stresses due to bends in the pipeline wall.

[c24] 24.The system of claim 14, further comprising enhanced detection by trending measurements of stored Barkhausen noise signals over a period of time for providing higher detection sensitivity than single absolute measurements of Barkhausen noise signals.

[c25] 25.The system of claim 17, wherein the one or more magnetic noise sensors connected to the instrumentation circuits comprises:

the one or more magnetic noise sensors connected to input terminals of one or more amplifiers in the instrumentation pack;

output terminals of the one or more amplifiers con-

nected to input terminals of one or more filters in the instrumentation pack;

output terminals of the one or more filters connected to input terminals of one or more detector circuits in the instrumentation pack;

output terminals of the one or more detector circuits connected to input terminals of a multiplexer in the instrumentation pack; and

an output terminal of the multiplexer connected to a data storage device in the instrumentation pack for storing multiplexed Barkhausen noise data.

[c26] 26. The system of claim 15, wherein the positioned one or more magnets and aligned one or more magnetic fields are included in an existing MFL inspection pig.

[c27] 27.A system for in-line stress measurement by continuous Barkhausen noise detection, comprising:

an MFL inspection pig including means for creating one or more magnetic fields circumferentially positioned in a pipeline wall aligned and moving parallel with an axis of the pipeline as the MFL inspection pig transits the pipeline;

means for sensing Barkhausen noise signals at one or more surfaces of the pipeline wall in one or more transition zones created by the one or more magnetic fields where there are strong magnetic field

gradients created by the MFL inspection pig;

means for amplifying, filtering, detecting, multiplexing and storing the sensed Barkhausen noise created by the moving magnetic fields of the MFL inspection pig; and

means for analyzing and interpreting the stored Barkhausen noise signals in relation to corresponding positions of the MFL inspection pig within the pipeline for determining stress magnitude and corresponding locations of stress in the pipeline wall.

[c28] 28. The system of claim 27, wherein the MFL inspection pig comprises:

one or more magnets each having a north pole and a south pole positioned on the circumferential surface of the MFL inspection pig movably contained within a pipeline;

one or more magnetic fields produced by the one or more magnets for producing magnetic fields in a wall of the pipeline aligned parallel to a longitudinal axis of the MFL inspection pig and the pipeline; and

means for moving the MFL inspection pig along the longitudinal axis of the pipeline.

[c29] 29. The system of claim 27, wherein:

the means for sensing Barkhausen noise signals comprises one or more magnetic sensors located at

transition zones adjacent to the poles of the one or more magnets and outside the one or more magnetic fields where there are strong magnetic field gradients in the pipeline wall for detecting Barkhausen noise in the pipeline wall;

the means for amplifying, filtering, detecting, multiplexing and storing comprises one or more magnetic noise sensors connected to instrumentation circuits in an instrumentation pack contained within the MFL inspection pig; and

the Barkhausen noise signals sensed for determining stress in the pipeline wall and stored in the instrumentation pack as the MFL inspection pig is caused to transit the pipeline along the longitudinal axis of the pipeline.

[c30] 30. The system of claim 27, further comprising enhanced detection by trending measurements of stored Barkhausen noise signals over a period of time for providing higher detection sensitivity than single absolute measurements of Barkhausen noise signals.